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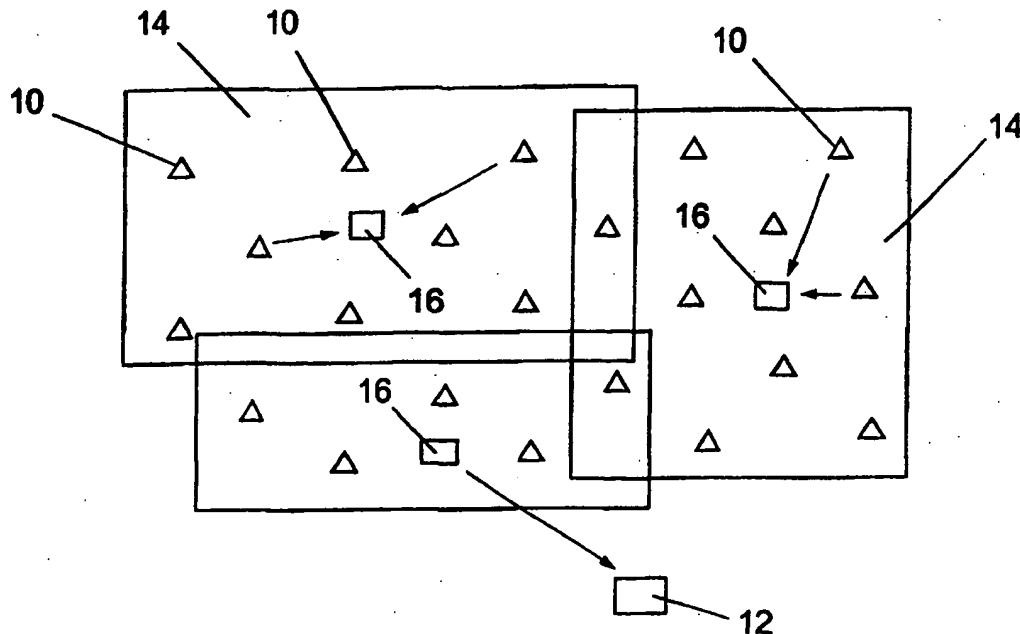
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(54) Title: SEISMIC ACQUISITION SYSTEM USING WIRELESS TELEMETRY



### (57) Abstract

A seismic acquisition system divides a survey terrain into a number of cells (14) each containing a cell access node (16) and a number of geophone units (10). The geophone units (10) transmit data in digital form to the respective cell access node (16) by wireless telemetry, and the cell access nodes (16) forward the data to a central control (12) by broadband channels.

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## 1 SEISMIC ACQUISITION SYSTEM USING WIRELESS TELEMETRY

2

3 This invention relates to seismic acquisition using  
4 geophones.

5

6 It is well known to conduct a geophysical survey of a  
7 land area by using an array of geophones in conjunction  
8 with either a succession of explosions or a continuous  
9 vibration applied to the ground by a vibratory  
10 apparatus.

11

12 Although the results obtained are valuable,  
13 conventional techniques are logistically slow, labour  
14 intensive, and costly. It is necessary to deploy a  
15 large number of geophones on a grid which has been  
16 previously surveyed. Each geophone string is  
17 individually wired to a central control unit. As the  
18 survey progresses, geophones in the rear must be  
19 disconnected, repositioned at the front, and  
20 reconnected. This procedure is extremely laborious,  
21 and the complexity of the connections gives a high  
22 probability of error. The scale of the problem will be  
23 understood when it is realised that a typical 3D  
24 seismic array involves up to 750 km of cabling.

25

1 An object of the present invention is to provide a  
2 means to simplify these procedures, and thus to reduce  
3 the time and cost of the survey by a significant  
4 factor.

5

6 Accordingly, the invention from one aspect provides a  
7 seismic acquisition system comprising a multiplicity of  
8 geophone units which, in use, are arranged in an array  
9 across a survey terrain; each geophone unit comprising  
10 means for deriving digital data representative of  
11 seismic movement of the earth's surface at the geophone  
12 location, and wireless telemetry means adapted to  
13 receive command signals from a central control and to  
14 transmit said digital data to the central control on  
15 command.

16

17 In a preferred form of the invention, the terrain is  
18 divided into a number of cells each of which contains a  
19 number of geophone units and a cell access node. The  
20 geophone units in a given cell communicate with the  
21 respective cell access node using wireless telemetry at  
22 a given frequency, with different frequencies used in  
23 adjacent cells.

24

25 The cell access nodes may communicate with the central  
26 control by radio, or by cable or fibre optic link.

27

28 The communication within each cell is preferably high  
29 frequency (most preferably 2.4 GHz band) low power.  
30 This permits a limited number of frequencies to be re-  
31 used across the terrain.

32

33 The means for deriving said digital data may comprise  
34 an analog geophone measuring velocity, coupled to an  
35 analog-to-digital converter.

36

1      Each of the geophone units is preferably provided with  
2      a memory for short term storage of said data, and for  
3      permanent storage of a unique code identifying that  
4      geophone unit.

5  
6      Preferably, each of the geophone units has a  
7      preamplifier and preamplifier control means remotely  
8      operable from the central control. The preamplifier  
9      control means may be operable to control the gain  
10     and/or an operating time window of the preamplifier as  
11     a function of the distance of that geophone unit from  
12     the location of the seismic signal source being  
13     monitored, and/or as a function of time.

14  
15     Each of the geophone units may additionally have its  
16     unique code physically embodied internally or  
17     externally, or electronically tagged on a  
18     microprocessor forming part of the geophone unit, or as  
19     an external display for example in the form of a  
20     machine readable bar code, all of which can be read by  
21     wireless method using existing hardware.

22  
23     The wireless telemetry means is preferably digital, and  
24     may comprise a dedicated wireless system, or may be  
25     provided by a cellular wireless system.

26  
27     From another aspect, the invention provides a method of  
28     conducting a seismic survey in which a number of  
29     geophone units are positioned in an array across a  
30     terrain of interest, a seismic signal (or a series of  
31     seismic signals) is generated to produce seismic data  
32     collected by the geophone units, the data for each  
33     geophone unit is stored at the geophone unit, and said  
34     data is transferred to a central location using  
35     wireless telemetry, at the same time or at a later  
36     time.

1 An embodiment of the present invention will now be  
2 described, by way of example only, with reference to  
3 the drawings, in which:

4

5 Fig. 1 is a schematic view of a seismic survey  
6 system;

7 Fig. 2 is a block diagram illustrating one form of  
8 geophone unit for use in the system; and

9 Fig. 3 is a schematic view of a survey area  
10 illustrating radio frequency allocation; and

11 Fig. 4 is a block diagram of a central control  
12 used in the system.

13

14 Referring to Fig. 1, a seismic survey across a  
15 "prospect" or area of terrain of interest is conducted  
16 by positioning a number of geophone units or remote  
17 acquisition units (RAUs) 10 at known locations,  
18 typically in a regular array. In the system of the  
19 present invention, each RAU 10 can receive signals from  
20 and transmit signals to a central control unit (CCU) 12  
21 using wireless telemetry.

22

23 The array may be divided up into cells as indicated at  
24 each with a transmitter/receiver or cell access node  
25 (CAN) 16 acting as a relay between the RAUs 10 and the  
26 CCU 12. This division may be required by the nature of  
27 the terrain, but is advantageous in any event since it  
28 allows the use of low power in the RAUs 10, thus  
29 reducing size and cost.

30

31 Fig. 2 illustrates an individual RAU 10 which may be  
32 used in the system of Fig. 1. The RAU 10 in Fig. 2  
33 uses a single conventional geophone or string(s) of  
34 geophones to provide velocity information at 20 in  
35 analogue form to an analogue to digital convertor 22  
36 via a preamplifier and filter stage 21. The digitised

1 information is stored at 24 for forwarding to the CAN  
2 16 via a transmitter/receiver 26 in accordance with  
3 control signals received from the CAN 16. These  
4 control signals and the forwarding of the digital  
5 information are by means of any suitable proprietary  
6 protocol.

7

8 The RAU 10 also comprises a power supply 28 and control  
9 circuitry 30. The power supply 28 suitably comprises  
10 rechargeable or disposable batteries and preferably  
11 also a solar panel.

12

13 Each of the RAUs 10 is identified by a unique code  
14 which may be stored in a dedicated area of the store 24  
15 as indicated at 24a.

16

17 The control circuitry 30 controls operation of the  
18 preamplifier 21 in two ways.

19

20 First, the gain of the preamplifier 21 is adjusted as a  
21 function of distance of the particular RAU 10 from the  
22 location of the seismic signal source; this provides  
23 more sensitivity at further distance from the source.  
24 This adjustment may suitably be made and changed as the  
25 location of the source is changed, the RAUs being  
26 stationary.

27

28 Secondly, the gain may also be varied with time as the  
29 return from the seismic signal source decays, with more  
30 preamplification being used to boost the signal as it  
31 decays. For example, an RAU close to the seismic  
32 signal source could be set to have an initial gain of  
33 2<sup>0</sup> which is used for the first second of the signal and  
34 is increased to 2<sup>1</sup>, 2<sup>2</sup> and 2<sup>3</sup> for each successive  
35 second, whereas a distant RAU may be set with an  
36 initial gain of 2<sup>4</sup>, increasing to 2<sup>5</sup>, 2<sup>6</sup> and 2<sup>7</sup>.

1       These two factors are programmable from the CCU 12.  
2  
3       The control circuitry 30 also controls the operation of  
4       the digital wireless telemetry such that the power  
5       output is variable, allowing the number of RAUs 10  
6       reporting to any given CAN 16 and the distance of any  
7       RAU 10 from any given CAN 16 to be programmed, allowing  
8       the design of the seismic surveys to be flexible.  
9       These factors are also programmable from the CCU 12.  
10  
11      In operation, the CCU 12 transmits a signal to  
12      indirectly activate the RAUs 10 prior to initiation of  
13      the seismic signal source and each unit then stores  
14      data for a given period after that signal. The CANs 16  
15      poll their respective RAUs 10 causing each RAU to  
16      transmit its stored information preceded by its  
17      identity code. By using different frequencies in the  
18      various cells 14, polling can proceed simultaneously in  
19      each cell, with the CANs 16 communicating with the CCU  
20      12 via a small number of broadband wireless links, or  
21      data cable or fibre optic links.  
22  
23      In a modification, RAUs may be used which each comprise  
24      two or more geophones operating with a single memory,  
25      control circuitry and transmitter/receiver.  
26  
27      The shape and size of the cells is determined by the  
28      range of the wireless transceiver, the terrain,  
29      obstructions, and to a lesser extent the weather. The  
30      RAUs in a given cell operate on one set of radio  
31      frequencies. Adjacent cells operate on different  
32      frequencies.  
33  
34      The telemetry system is able to re-use frequencies in  
35      non-adjacent cells. Fig. 3 illustrates this with  
36      reference to a survey area crossing a ridge (indicated

1 by contour lines 37). Given that the radio  
2 transceivers have a limited range, once outside that  
3 range a given frequency can be re-used in another cell.  
4 Thus radio frequencies can be re-used on a rolling  
5 basis to minimise the number of frequencies required by  
6 the system.

7  
8 The radio system may particularly operate in the 2.4  
9 GHz band at low power. High frequencies of this order  
10 decay quickly with increasing distance, which allows a  
11 limited number of frequencies to be used for an  
12 unlimited number of cells. The 2.4 GHz band is  
13 particularly preferred as this is a licence-free band  
14 in many territories.

15  
16 In the event of a CAN receiving signals from a number  
17 of different cells, the system software can de-  
18 duplicate the signals by deleting the weaker signals.

19  
20 A suitable resolution will be obtained by each geophone  
21 generating 24-bit information at a repetition rate of  
22 500 Hz (2ms sample rate). The bandwidth requirement of  
23 the polling system may be reduced by using known data  
24 compression techniques in the RAUs 10 or CANs 16.

25  
26 As one example, for a 24-bit sample at 2ms intervals,  
27 the maximum data rate per geophone unit would be 12  
28 kbits/s, and for a sector with eighty geophone units,  
29 the sector base station would have a maximum data rate  
30 of 1 Mbits/s. There are available low cost  
31 radiotelemetry modules suitable for this data rate; for  
32 example, the "Prism" radio chipset from Harris  
33 Semiconductor Limited can handle up to 4 Mbit/s.

34  
35  
36 Fig. 4 shows one suitable form of CCU. Data is

1       captured on a commercially available seismic  
2       acquisition recording unit 44 of known type. This  
3       issues timed shot commands at 46. Each shot command  
4       causes a sync pulse generator 48 to generate a sync  
5       pulse 1 to activate the geophones, and a series of  
6       timed sync pulses 2<sub>i</sub> to control the polling. The sync  
7       pulses are encoded and transmitted at 50 via a  
8       transmit/receive switch 52, which also gates incoming  
9       data signals to a receiver and decoder 54 to supply  
10      data for the recording unit 44.

11  
12      In a modification of the CCU, the sampling interval is  
13      reduced stepwise in time. As one example, instead of  
14      sampling every 2 ms for a total of 4s, the sampling  
15      rate would be every 2 ms for the first second, every 4  
16      ms for the next second, every 6 ms for the third  
17      second, and every 8 ms for the fourth second. The  
18      reason for this is that high frequency information is  
19      attenuated with time in comparison with low frequency  
20      information, and therefore the further one is away in  
21      time from the input event the less high frequency there  
22      is to be measured and the sampling rate can be reduced.

23  
24      It is of course necessary for the CCU 12 to have  
25      information defining the position of each of the RAUs  
26      10. This may be achieved, as is currently done with  
27      wired systems, by securing the RAUs 10 at positions  
28      previously marked by conventional surveying. To assist  
29      in loading information defining which RAU is at which  
30      location, each RAU may conveniently be provided with an  
31      external, machine-readable label such as a conventional  
32      bar code with that unit's unique identity code. The  
33      personnel installing the units can thereby enter the  
34      location number and the corresponding geophone code in  
35      a simple manner into portable recording apparatus for a  
36      subsequent downloading into the central control 12.

1 As an alternative, each RAU could include an electronic  
2 positioning means which would enable the RAUs to be  
3 positioned on the terrain without a preliminary survey  
4 with the position of each RAU thereafter being  
5 established by the CCU 12 by polling location data from  
6 the RAUs 10. Such electronic positioning means could  
7 be provided by a GPS system. Positional accuracy can  
8 be improved by use of Differential GPS (DGPS). Rather  
9 than incurring the expense of DGPS in each RAU, since  
10 the RAUs are at fixed locations the positional  
11 information can be loaded into the RAU when it is  
12 installed; conveniently this could be done by infra-  
13 red, radio or any other suitable means of short range  
14 data transfer linking from a portable DGPS apparatus  
15 which also includes the bar code reader.

16  
17 Alternatively, the position of the CAN for each cell  
18 could be fixed by a GPS receiver in the CAN, and the  
19 relative position of each RAU with respect to its CAN  
20 determined by a relatively simple local system.

21  
22 It is likely that a dedicated wireless telemetry system  
23 would require to be used, with one frequency to carry  
24 commands from the CCU 12 indirectly to the various RAUs  
25 10 and a number of separate frequencies to carry data  
26 in reverse. In certain locations however it might be  
27 possible to use systems similar to cellular telephones  
28 for both commands and data.

29  
30 Other modifications and improvements may be made to the  
31 foregoing within the scope of the present invention, as  
32 defined in the following claims.

1

2 CLAIMS

3

4 1. A seismic acquisition system comprising a  
5 multiplicity of geophone units arranged in an  
6 array across a survey terrain, wherein each of  
7 said geophone units comprises means for deriving  
8 digital data representative of seismic movement of  
9 the earth's surface at the geophone location, and  
10 wireless telemetry means adapted to receive  
11 command signals from a central control and to  
12 transmit said digital data to said central control  
13 on command.

14

15 2. A seismic acquisition system as claimed in Claim  
16 1, wherein said survey terrain is divided into a  
17 number of cells, each of which contains a  
18 plurality of geophone units and a cell access  
19 node.

20

21 3. A seismic acquisition system as claimed in Claim  
22 2, wherein said plurality of geophone units within  
23 a given cell communicate with said cell access  
24 node using said wireless telemetry at a given  
25 frequency, with different frequencies used in  
26 adjacent cells.

27

28 4. A seismic acquisition system as claimed in Claim  
29 3, wherein said communication within each cell is  
30 high frequency (2.4 GHz band) low power.

31

32 5. A seismic acquisition system as claimed in Claim 3  
33 or Claim 4, in which a given frequency is used in  
34 a number of non-adjacent cells across the terrain.

35

36 6. A seismic acquisition system as claimed in any of

1       Claims 2 to 5, wherein said cell access nodes  
2       communicate with said central control by radio, by  
3       cable, or by fibre optic link.

4

5       5. A seismic acquisition system as claimed in Claims  
6       3 and 4, wherein said communication within each  
7       cell is high frequency (2.4 GHz band) low power.

8

9       7. A seismic acquisition system as claimed in any  
10      preceding Claim, wherein said means for deriving  
11      digital data comprises an analog geophone  
12      measuring velocity, coupled to an analog-to-  
13      digital convertor.

14

15      8. A seismic acquisition system as claimed in any  
16      preceding Claim, wherein said geophone units are  
17      provided with a memory for short term storage of  
18      said data, and for permanent storage of a unique  
19      identification code.

20

21      9. A seismic acquisition system as claimed in any  
22      preceding Claim, wherein each of said geophone  
23      units has a preamplifier and preamplifier control  
24      means.

25

26      10. A seismic acquisition system as claimed in Claim  
27      9, wherein said preamplifier control means is  
28      operable to control the gain and/or an operating  
29      time window of said preamplifier as a function of  
30      the distance of said geophone unit from the  
31      location of the seismic signal source being  
32      monitored, and/or as a function of time.

33

34      11. A seismic acquisition system as claimed in Claim  
35      8, wherein each of said geophone units has its own  
36      unique code physically embodied internally or

1       externally, or electronically tagged on a  
2       microprocessor forming part of said geophone unit,  
3       or as an external display such as a bar code.  
4

5       12. A seismic acquisition system as claimed in any  
6       preceding Claim, wherein said wireless telemetry  
7       means is digital.  
8

9       13. A method of conducting a seismic survey, wherein a  
10       plurality of geophone units are positioned in an  
11       array across a terrain of interest, a series of  
12       seismic signals is generated to produce seismic  
13       data collected by said geophone units, the data  
14       for each of said geophone units is stored at said  
15       geophone unit, and said data is transferred to a  
16       central location using wireless telemetry, at the  
17       same time or at a later time.  
18

19       14. A method according to Claim 13, in which said  
20       survey terrain is divided into cells, each of  
21       which contains a plurality of geophone units and a  
22       cell access node, said data being transferred from  
23       each geophone unit to its respective cell access  
24       node by wireless telemetry, and from each cell  
25       access node to said central location by radio, by  
26       cable, or by fibre optic link.  
27

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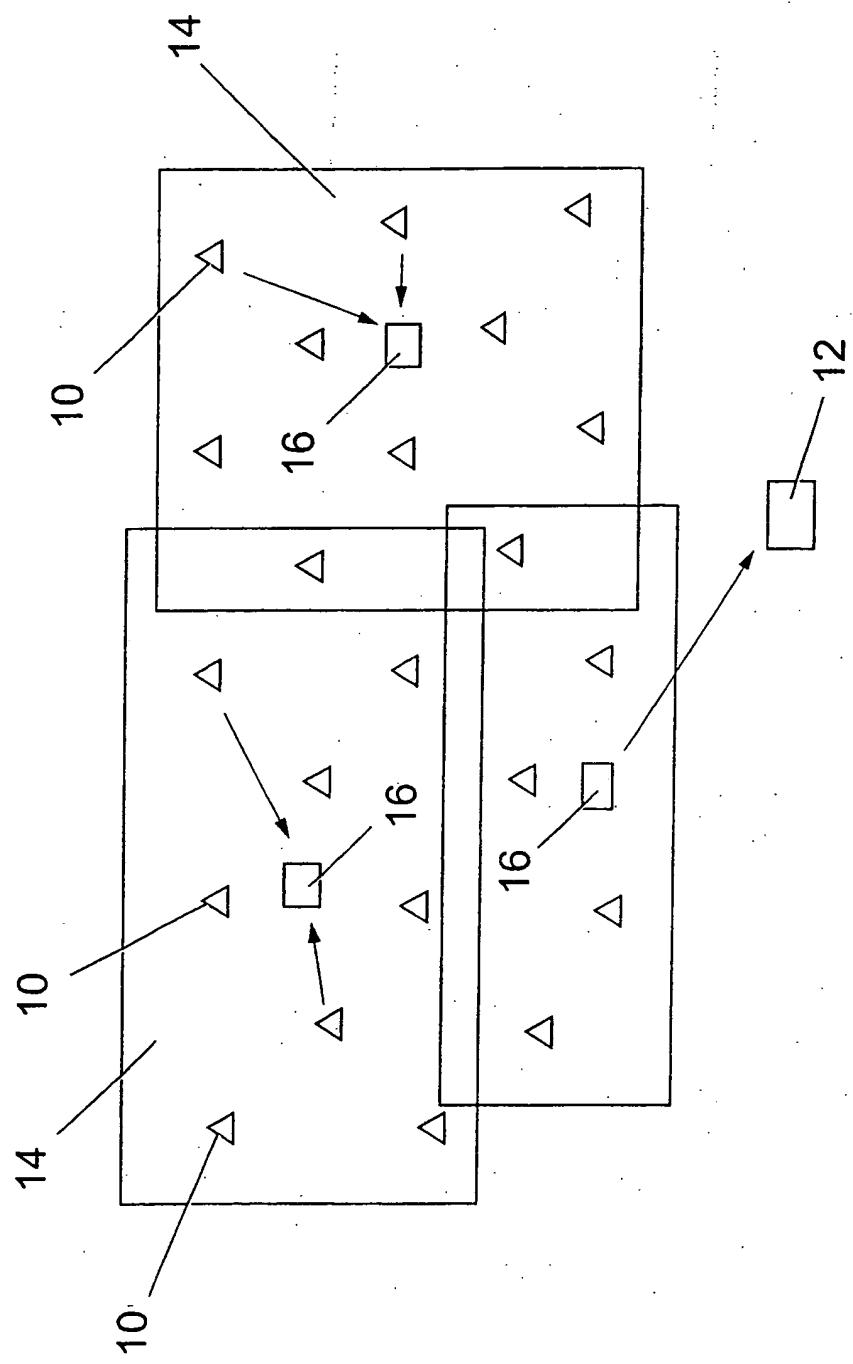


Fig. 1

2 / 4

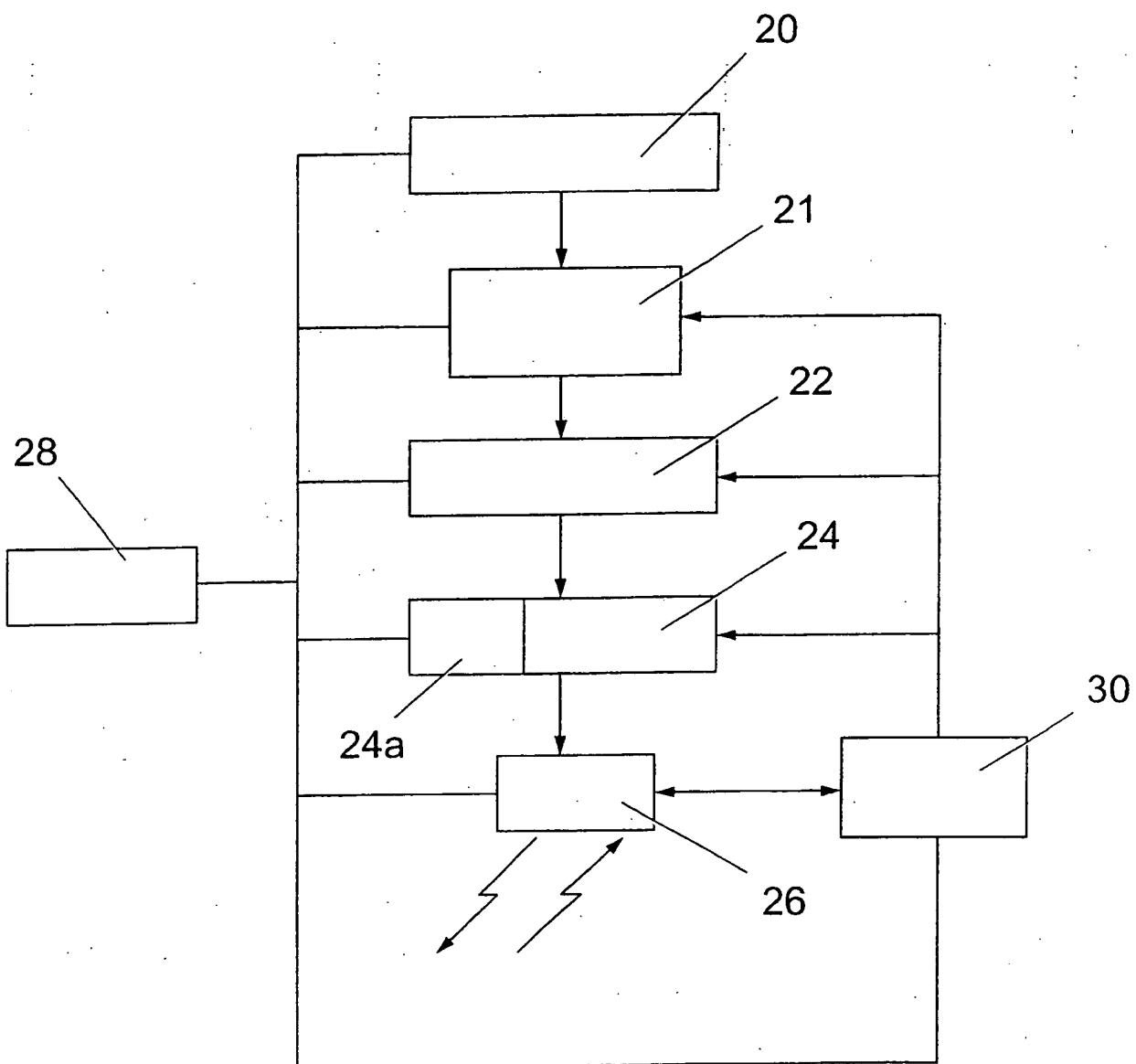


Fig. 2

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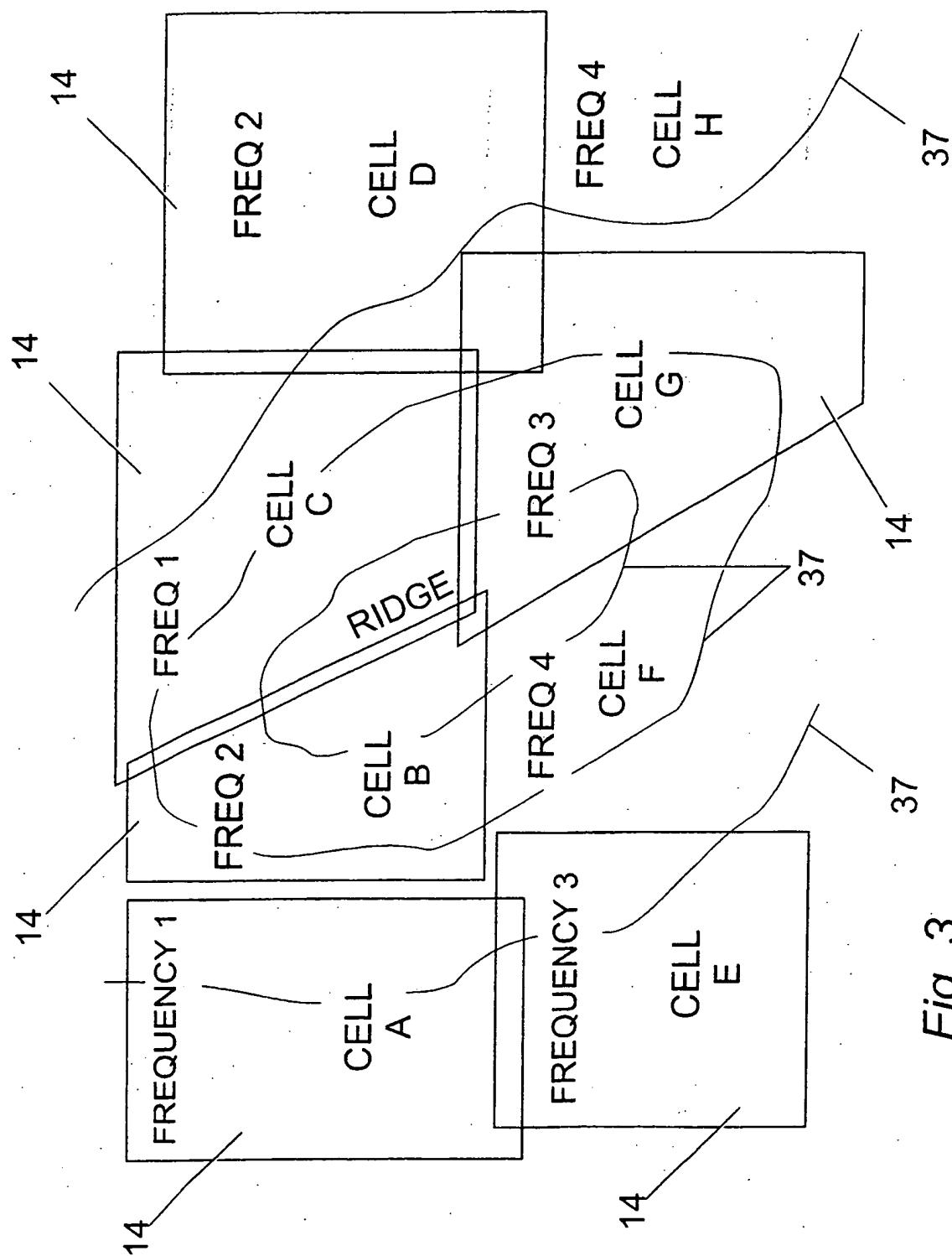


Fig. 3

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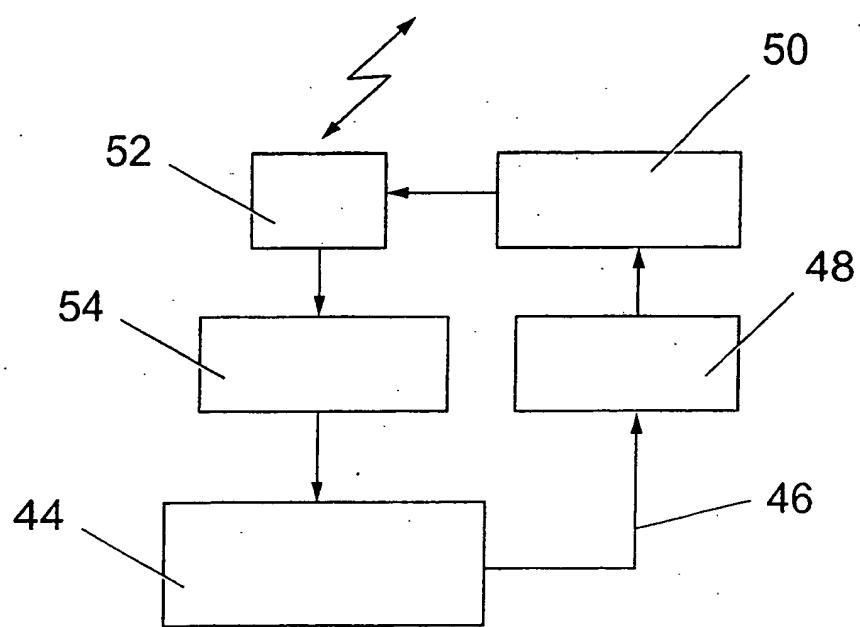


Fig. 4

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 97/02924

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC 6 G01V1/22

According to International Patent Classification(IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 815 044 A (DECONINCK BERNARD ET AL) 21 March 1989 see abstract see column 3, line 47 - line 53 see column 4, line 34 - line 68 see column 7, line 62 - column 8, line 47	1-3, 6-8, 11, 13, 14
A	---	4, 5, 9
A	DE 195 19 164 A (INST FRANCAIS DU PETROL) 14 December 1995 see figure 1 ---	6
A	EP 0 646 809 A (INST FRANCAIS DU PETROL) 5 April 1995 see column 1, line 30 - line 50 ---	9, 10
		-/-

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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# INTERNATIONAL SEARCH REPORT

International Application No

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